THE MOSQUITO CAMPAIGN AS A SANITARY MEASURE

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Insects as factors in sanitary work have been very little regarded until recent years and, practically, only since it was demonstrated that mosquitoes of certain species were necessary intermediate agents in the transmission of certain febrile diseases. The history of that demonstration has been well written by Howard, Blanchard, Theobald and others, and need be only referred to here. Since that time, attention having been directed to the class, certain ticks, lice, fleas and flies have been convicted as carriers or transmitters of a variety of diseases of man and other animals, and this branch of entomological research has become of the highest practical importance.

To emphasize the agency of one of the carriers, Howard has proposed that the common house fly be hereafter known as the typhoid fly and, while there are objections to the name, it is not inadvisable to follow him; remembering the while that it is really only *a* typhoid fly, and not the only species capable of carrying the morbific organism. Nor is its ability as a carrier confined to typhoid or even enteric diseases. Any pathological germ, microbe, bacillus or other creature capable of being taken up and carried from one place to another may be transported by this omnipresent pest, and the comma and colon bacillus are equally liable to be ingested and again discharged in virulent condition.

There are the radical differences between a transmitter and a carrier of a disease "germ," for a transmitter is usually agent for one parasitic organism only, while a carrier may transport a number. *Stegomyia calopus* is a transmitter of yellow fever only and, so far as our knowledge extends at present, the only transmitter of that disease. Certain species of *Anopheles* are transmitters of the various forms of malaria and, so far as we know, the only transmitters of those diseases. Eliminate *Stegomyia* and *Anopheles* and at the same time yellow and malarial fevers have been disposed of; but even if every house fly could be at one blow destroyed.

typhoid, cholera and other enteric fevers would yet continue to exist and would even appear in epidemic form when conditions favored.

It is matter of interest also to note that by far the most important of the transmitters of disease belong to the order *Diptera* or two-winged flies, the most highly specialized of all the insect orders, and probably the most recent in point of development. I am not unmindful of the fact that mites and ticks are sources of danger and agents in the transmission of Texas fever in cattle and spotted fever in man; but as a general statement and applied to the true insects alone, the order *Diptera* contains the most dangerous of all our species from the sanitary standpoint.

Any effort to lessen or altogether eliminate any of the mosquito carriers of disease is therefore worthy of the support of sanitary authorities, whether national, state or municipal, and this fact has been recognized to the fullest extent by the United States Government authorities at work in the Panama Canal Zone.

A brief consideration of the life cycle of mosquitoes is desirable, to understand the extent and variety of work necessary in any comprehensive campaign, for while there are some similarities there are also many differences in habits and development. All mosquitoes are wrigglers in the larval stages, and all require water for development; that is the one feature identical in the life history of all the species so far as known to me. But there is the greatest divergence as to the kind of water preferred and in the conditions under which they occur. Some species breed only in woodland pools, some only on salt marshes, some only in tree holes filled with water, some only in the small collections of liquid found in pitcher plants and other water-storing plants, some only in clean water, while a few are specifically dirty-water mosquitoes. In the tropics the divergencies in breeding habits are still greater, but for my present purpose the consideration of species is confined to the types occurring in the Middle Atlantic states and immediately adjacent regions.

It is particularly to be noted in this connection that the dirty-water breeders are those most closely associated with man—*Stegomyia calopus* and *Culex pipiens* for instance—and are rarely if at all to be found far removed from his settlements. They have specifically adapted themselves to live in association with him and in the

liquid wastes that he produces. The larva of the house mosquito—*Culex pipiens*—lives indoors and out, in any receptacle containing water—a fruit jar, a flush tank or even an unused bowl of a water closet, in cesspools, manure pits, sewer catch-basins, gutters, etc. There is no liquid so filthy, so it be actually a liquid, as to daunt this species. And here comes a thought for those who consider the house mosquito leniently, as something to be philosophically endured because of the trouble and expense of dealing with him otherwise. The food of these wrigglers consists of the micro-organisms found in this waste and foul water—of the specific and morbific organisms from all the excreting organs of the human and animal body, of those producing ferments and decay and of about everything that the sanitarian deems most vile and objectionable—and this creature, so nourished and built up, has been and is allowed in our houses, allowed to feed upon our blood and upon that of our children, allowed to puncture the skin and inject into our veins the poisonous salivary secretions distilled out of all this refuse! Is it at all wonderful that sometimes a mosquito bite sets up serious disturbances even where pathological organisms are not carried! Strictly speaking, although it carries no specific disease, *Culex pipiens* is a greater nuisance than the malaria transmitting *Anopheles* because of its greater abundance, its wider range, its vicious bite and its more persistent efforts to get indoors and into our dwellings.

Now, while all mosquito larvæ or wrigglers are water dwellers and feeders upon minute or other organisms, their method of feeding is not identical, nor is the level at which they feed or the method of breathing the same. A very few wrigglers are carnivorous, feeding upon others of their kind. All the *Anopheles* are top feeders, skimming spores and other material that falls upon the surface, and these forms may exist in very shallow water, along the grassy edges of streams or pools, or in partially over-grown swamps among or even over partially submerged leaves, the body resting parallel to or upon the surface of the water. These species depend entirely upon atmospheric air for their supply of oxygen, and that is drawn in through a short tube at the anal end of the body. The species of *Culex* as a rule feed upon organisms living beneath the surface or even on the bottom, coming to the surface only to breathe by means of a longer tube than that of *Anopheles*. They never lie on the surface and require deeper water than those of the preceding

type. A few species have, besides the anal tube, tracheal gills developed at the hind part of the body, and these need not necessarily come to the surface to breathe: they are able to and do obtain a large portion of their supply of oxygen directly from the water. A very few species, of which *Culex perturbans* is our only local representative, are bottom feeders and get their supply of air out of large-celled plants. Here the anal tube is modified into an auger-like structure which is forced into a plant stem or root, and there the insect rests, getting its oxygen supply out of the plant

Manifestly, while we can use oil to kill the wrigglers of those types that get their air supply above the surface, we cannot so reach those that are not surface breathers. Fortunately all our pestiferous forms except *perturbans* are dependent upon atmospheric air and can be reached with oil; but where *perturbans* is the species in fault none of the ordinary methods of procedure are available.

There is a still greater divergence in the egg-laying habits of the insects. The house mosquito and a very few others lay them in a raft or boat on the surface of the water, and that is the form in which they are commonly seen, because these include the common, annoying forms. The species of *Anopheles* also lay their eggs on the surface, but singly or in little groups, never bound together in a boat or raft. Eggs so laid usually hatch within a day or two; but *C. perturbans is* an exception in this respect as well as in larval habit.

By far the larger proportion of species do not lay their eggs on or in water at all or, if they do, the eggs do not remain on the surface. All of the salt marsh forms except *C. salinarius* and most of the woodland species lay their eggs in mud or in moist depressions where water has been and is likely to be again. Such eggs often retain their vitality for long periods, measured not by days, weeks or months, but by years, and they may be dried out completely for a long time without losing the power of development. When circumstances favor, the larvæ hatch promptly, so that after a year or two of dormancy in the egg stage develop into the adult form within a week or ten days.

So there is great divergence in the length of adult life, in the habits of the adult and in the number of broods. Most of the woods mosquitoes have only a single brood annually, developing in early spring from eggs that have lain dormant during the winter, and

the adults from that brood may and generally do live until after midsummer, biting as often as they get a chance to do so. Some of these woodland forms never leave the shelter of the trees even in pursuit of food; but some of them will fly some distance out at night. In such cases settlements in or along the edge of woodland may be troubled on piazzas or in open rooms; but the insects rarely make any effort to get indoors and do not remain. The species that breed on the salt marshes—except *salinarius*—also winter in the egg-stage and develop early in spring; but of these there may be from four to eight broods during the summer, depending upon weather conditions. These species develop only after a storm that fills the marsh depressions or after an unusually high tide or a combination of the two. Unlike most other mosquitoes these marsh forms have a peculiar migratory instinct developed. Within a day or two after a heavy brood comes to maturity, if there comes a warm quiet night with only a moderate wind, thousands—yea millions of the insects will rise as if by concerted action high in air and will partially fly, partially drift for many miles with the wind, settling down over the country many miles from their point of origin. I have watched *cantator,* one of the salt marsh forms come into a window in Philadelphia before midnight, after a flight that could not have been much less than forty miles, and I have had reports of a rising up of *sollicitans* from the marsh along the Barnegat shore and of the presence of the swarm in the pines early next morning, where none were the day before. The arrival of *tæniorhynchus* has been actually noted at the brow of the Palisades in New Jersey on an east wind when the nearest known breeding place for the species was at the mouth of the Bronx River in New York State. None of the inland species so far as I know them have this migratory habit so well developed, though *perturbans* possesses it to some extent. None of these forms are really house mosquitoes in the sense that they will make special efforts to get indoors. They will fly through an open door or window or follow in a victim; but they are readily kept out by even an imperfect screen and they are usually at least as anxious to get out as they were to get in. They never remain to hide or to hibernate.

The species of *Anopheles* hibernate in the adult stage and they are house mosquitoes in the sense that they try to get indoors and will remain there by preference until the desire to oviposit develops.

They do not breed by preference in dirty, and not at all in filthy, water. They frequent grassy edges of pools, ponds or sluggish streams, and are sometimes found in water barrels, pails, tubs or the like. They are not so closely associated with humanity as *C. pipiens,* but find its company desirable as food. These species do not begin breeding very early and are rarely seen in the larval stage much before midsummer; but they will continue to breed until actual frost, and there may be four or even five broods during the season. Beginning with the latter part of September some of the impregnated females seek shelter in barns, cellars, outhouses, in sheltered overhangs among roots of trees and begin their winter dormancy. This dormant population increases until late October; but the specimens maturing later do not seem to mate, and die off. Over 5,000 specimens of *Anopheles punctipennis* have been taken during the winter in a single barn, and *Anopheles* was not a troublesome form in that vicinity either. It was simply the best available place for the purpose in the neighborhood. The species of this genus do not ordinarily fly for great distances. They seem to require blood food to mature their eggs and will travel far enough to find that. Half a mile is well within their compass and I feel sure that is not the limit; on the other hand they will under ordinary conditions fly no further than necessary and in malarial outbreaks a distance of 1,000 feet from the breeding area for the species is rather unusual, while 500 feet is common.

The house mosquito, *C. pipiens,* derives this name from its efforts to enter into our dewllings and its determination to stay there as long as possible. From its breeding habits it is also termed the rain-barrel or dirty-water mosquito, and it might with equal justice be called the sewer or sewage mosquito. It also hibernates in the adult stage, and preferably in cellars, where it rests on the side walls or ceilings, in dark and slightly damp places. In very cold weather the specimens are dormant and not easily started into activity; as it becomes warmer they fly ever more readily, and in May are ready to leave and start breeding. They do not bite during the winter for that would start development of the ovaries and, unless the insect found a chance to oviposit, it would result in its death before spring. Breeding is continuous during the summer and the number of broods depends only on the supply of dirty water. From egg to adult requires only eight days, and

a week later the new adults are ready to reproduce their kind. During midsummer when wrigglers become numerous and pools small, an undersized brood is apt to develop and these specimens find little difficulty in getting through the ordinary wire-netting screens.

This species will get into houses if it possibly can, through openings of all kinds and has even been accused of getting down the chimney and out through fire-places. It requires the closest kind of care and most persistent watching to exclude them and even then a few specimens manage to get in during the summer and the cellar becomes filled during the winter. After a summer like that of 1910 a cellar population may number hundreds or thousands, depending upon the ease of entry.

From what has been said it is apparent that the primary factor upon which success depends is a knowledge of the species in fault. Knowing this we are in position to deal with the species with a fair prospect of success.

In suburban communities where any amount of woodland remains and the houses are more or less surrounded by trees, woodland species are apt to be troublesome early in the season, and if that proves to be the case, the breeding pools can be very easily located and abolished. Where they can be drained that is the safest and most permanent disposition to be made of them. Where that is not possible the depressions may be filled with leaves, branches or other broken woodland rubbish sufficient to absorb the water or completely cover it. That will serve to prevent access by the female mosquitoes and will prevent them from laying eggs. Where neither draining nor filling is feasible or possible, the breeding area may be covered with oil as soon as larvæ are found which will usually be in April. As there is only one annual brood of these pests, one treatment only, sufficient to destroy all the larvæ then present, is necessary to secure exemption for the summer.

As water is necessary to enable the insects to develop, so it is only necessary for us to locate the water in which these wrigglers breed, to enable us to deal with them. And that leads to the statement that by no means all water areas are mosquito breeders. As a rule the larger and deeper the pool, the less the danger. Wrigglers will not develop in areas swept by the winds or in "ripple" areas. Nor can they maintain themselves in pools or

ponds containing fish, provided the edges or banks are sufficiently clean to permit the fish to reach all portions of it. In grassy or overgrown edges or areas larvæ will breed. Ponds or pools covered with duck-weed are safe and so are pools filled with the stringy *Spirogyra*. Deep cold swamps breed no mosquito larvæ nor do dense overgrown cat-tail areas. Many campaigns have failed because all the efforts were made against and work done on areas where no breeding occurred while the places where the species really developed were unnoticed. Flowing streams are not often sources of danger, especially where they contain fish; but they may become so in a droughty period or when the water is low and the flow is interrupted.

Where *Anopheles* is in fault the larger water bodies must be examined and if an overgrown pond or a sluggish stream is found in fault, it will mean cleaning up to enable fish to operate, or cleaning out, to improve the flow of the stream.

Where *perturbans* is in fault each case must be dealt with according to local conditions and no general rule can be laid down.

If the salt-marsh species is at fault an inland community may find itself absolutely helpless. There are hundreds of square miles of mosquito ridden territory in New Jersey where not a single mosquito breeds and where the residents can only suffer or join in aid of the state fight.

Where the ordinary house-mosquito is in fault it means close, sanitary, house-to-house inspection and in this campaign every householder should join. Water barrels and cisterns should have every opening closely screened with close-meshed wire or a double netting. Cess-pools should be sealed or, if ventilated, the ventilating pipe should have a double wire netting. Every depression capable of holding water should be filled, or periodically oiled, and every sewer catch-basin or settling basin should be oiled periodically during the summer. Once every ten days is sufficient in periods of drought, and within a week after every rain a coating of oil should be put on. To enumerate all the places that should be looked after is impossible, and should be unnecessary when we have learned that every pool, puddle, or receptacle containing water may be dangerous.

In a very wet season there is danger because then many places where water ordinarily evaporates promptly, may be kept filled

long enough to develop the insects. But in such a season the sewers and sewer catch-basins rarely become sources of serious trouble. In a very dry season the sewer basins become the source of most intensive breeding, and small streams carrying off surface water become reduced to breeding puddles. Of the two the droughty season breeds more city and town mosquitoes than the rainy one.

The campaign should begin in winter, against the hibernating species in houses. I have tried many sorts of fumigants and more have been tried by others; but the only reliable destructive material that I have found is Mim's Culicide. That is a mixture of carbolic acid crystals and gum camphor, using equal parts, by weight. Liquefy the carbolic acid crystals by a gentle heat, break up the gum camphor into small pieces and pour the liquid acid slowly over the camphor. The acid will dissolve the camphor completely and the resulting liquid is permanent and only slightly volatile at ordinary temperatures. It volatilizes rapidly, however, in a shallow dish over the flame of an alcohol or other lamp and the vapor is death to flies and mosquitoes. Three ounces will suffice for 1,000 cubic feet in a tightly closed room, and it will require about half an hour to evaporate that amount. The vapor is not poisonous to man, is not destructive to metals or fabrics and is disinfectant in quality. In a large cellar there should be fumigants at several points to secure equal distribution of the vapor and equal effect throughout the cellar. The material is not explosive, but is inflammable and should be used with that fact in mind.

In New Jersey the sanitary position of the mosquito question is determined in the general health law of the state which defines among the nuisances "waters in which mosquito larvæ breed," and over these local boards of health have the same jurisdiction as over any other nuisances, with absolute power to abate.

The dual nature of the problem is strikingly illustrated in this state with its long coast line bordered by salt marshes of relatively enormous extent. More than half the area of the state was periodically overwhelmed by flights from these marshes and perhaps ninety per cent of all the mosquitoes in South Jersey were bred on the salt marshes. It was manifestly useless to preach local campaigns here where, even across the two ranges of the Wasatch Mountains, no local campaign could promise exemption from trouble. Nor could the thinly settled townships in which these salt marshes

occurred, be reasonably asked to abate the nuisances for the benefit of the more densely settled localities inland. There was only one authority fit to cope with the problem and that was the state itself. The value of the New Jersey seashore for summer resorts offered an additional inducement for state interference, and $350,000 was appropriated for draining the salt marshes, of which $83,500 has been made actually available. It seems like a terrific task to undertake the extermination of mosquitoes from an area of over four hundred square miles of desolation; nevertheless the work is in progress and up to the present time the cost has been within the estimates upon which the original appropriation was based, notwithstanding the fact that the cost of labor has been materially increased. Over four million lineal feet of ditches have been dug and over 25,000 acres of salt marsh have been made approximately mosquito proof. The character of the problem has been changed in the more northern localities, and it has become a local one in which the local municipalities are now concerning themselves and may count on success.

On the salt marshes the areas are first carefully surveyed to determine where breeding places exist. The aid of the local board of health is then invoked and notice is given to marsh owners making them acquainted with the facts and the law. They are given an opportunity to abate in their own way if they will, but if they do not—as generally happens—the entire area is drained in one block, under a general plan, and the work is paid for by the state. The matter is not really so serious as it looks at first blush, because the marshes are peaty in character and the water runs out easily. The ditches are thirty inches deep, usually ten inches in width, and placed about 200 feet apart in ordinarily bad areas. Some very rotten marsh is more thoroughly ditched and sound level marsh is not interfered with at all. These ditches through the turf stand indefinitely and, owing to their narrowness and depth, never grow up from the bottom. If not interfered with they will drain the marsh of surface water within forty-eight hours after being flooded by storm or tide, and will thus prevent the maturing of such larvæ as may hatch. There is no pretense of reclaiming the marsh for agricultural purposes, and all the ditches connect with tidewater so that the character of the land is not changed. But the character of the grass is affected by the drainage and

it becomes different in type and better, giving also much larger crops.

The work has been in progress for only four years and has just begun to show effects, but as the area treated is enlarged and the benefits become evident over a greater region it is hoped that more co-operation will be secured and more rapid progress made. The additional comfort secured where mosquitoes are absent has, in some localities, already brought crowded houses and induced building so that as a mere investment the work will eventually pay heavily. In the additional benefits secured by the person seeking rest and health at the seashore, the return cannot be measured by money values.

In the local campaign, the state organization acts in an advisory capacity only. It will make surveys, inspections and reports for any municipality desiring the same, and it will advise as to what should be done. Experiments are made with oils and other materials suggested or recommended for the control of the insects in any stage, and annual reports are made and published, showing the progress of the work and the information obtained.

Recently an organization has been formed by representatives of boards of health from a group of counties centering about Newark, Jersey City and Elizabeth, and for the benefit of these an inspector will be maintained merely to give notice to the local authorities of developments requiring action to control or destroy breeding places. Efforts will be made to secure permanent drainage or filling of the larger swampy areas, the diversion of small brooks carrying surface waters into trunk sewers, and the elimination of all the small breeding areas by orders of the local boards of health.

No one who has not had actual experience can realize in how many different kinds of places mosquito wrigglers can be found, especially in an active manufacturing city. Wherever water is stored in tanks for any purpose they have been found: in a pickle factory a lot of seventy-five hogsheads stored in a yard were partly filled with water to prevent shrinkage, and thousands of wrigglers were in each, supplying the neighborhood for squares round about with mosquitoes. In fire-buckets, even in halls of hotels they are not uncommon, and in the thousand and one different sorts of containers of the hundreds of factories, there is almost unlimited opportunity for mosquito propagation. Even in dwellings a neglected

aquarium has been found infested, the flush tank of a rarely used closet and the exposed trap of a shower bath serving as further examples of wriggler adaptation.

The sanitary officer in charge of a municipal mosquito campaign has no light task and his first effort, after educating himself, must be to educate his constituency to co-operate with him.